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EDITOR, C. A. CHANT ASSISTANT EDITOR, RUTH J. NORTHCOTT

David Dunlap Observatory
Richmond Hill P.O., Ont.

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THE TRANSIT OF MERCURY, NOVEMBER 14, 1953

RECORDS of the transit of Mercury have been received from twenty groups of observers. Although the majority were from the Toronto region, reports came also from such widely separated regions as Griffin, Ga. and Saskatoon, Sask. In Toronto the weather cleared on the morning of the transit, much to the pleasure of the local observers, especially those who experienced the cloudy skies of the 1940 transit. Unfortunately the efforts of the Montreal and Ottawa Centres to observe the 1953 transit were defeated by clouds.

The table, in two parts, summarizes the information received as this JOURNAL goes to press: the first part gives the names of the observers, place, longitude, latitude, altitude in metres, diameter of telescope objective in inches and the kind of telescope, *L* for refractor, *M* for reflector; *p* indicates a projected image. The second part of the table gives the recorded times. The observations are arranged in order of increasing longitude. The observers in the Toronto region were divided into two main groups, one on the University of Toronto campus under the direction of Dr. W. R. Hossack, and one at the David Dunlap Observatory, Richmond Hill. There were three groups who observed independently in Toronto. The Yankton, South Dakota, observations are the average of values obtained by two independent observers. The Regina group reported two sets of observations, with a careful study of the rates of the watches used for the observations; five telescopes were used. In general observers had reasonably good seeing, although some wind vibration was reported. The Saskatoon observers had very thin cloud.

The observations are being forwarded to the United States Naval Observatory and may be of considerable value. This transit may prove to be of unexpected interest since observations indicate a time of transit earlier than the predicted one. An increase in the period of rotation of the earth could result in such an effect.

R. J. N.

Observers	Place	Long.	Lat.	Alt.	Tel.	1st Contact E.S.T.	2nd Contact E.S.T.	3rd Contact E.S.T.	4th Contact E.S.T.
U. of T. campus groups		h m		m	in.	h m s	h m s	h m s	h m s
1. L. H. Clark, W. Sherrick	Toronto	5 17.6	+43°40′	116	4 Lp	..	..	13 08 01	13 11 17
2. K. Frenkel, A. Campbell					6 Mp	..	..	13 08 02	13 11 27
3. D. Griffin, E. Greenwood					2.4 L	..	..	13 08 06	13 11 17
4. J. Ketchum, W. R. Hossack					3 Lp	..	..	13 07 58	13 11 12
5. P. Locke, L. Locke					6 Mp	..	..	13 07 42	13 11 27
6. K. McCulloch					4 Lp	..	..	13 08 02	13 11 17
Independent Toronto groups									
7. J. E. Crawford	Toronto	5 17.6	+43 40	116	3 Lp	..	..	13 09 12	13 10 57
8. F. K. Dalton					4 L	10 37 30	..	..	..
9. W. Johnson, N. Dewick					6 Mp	..	..	13 08 47	.. ..
Dunlap Observatory groups									
10. B. R. Creeper	Richmond Hill	5 17.7	+43 52	244	6 Lp	..	10 39 53	..	..
11. J. F. Heard, D. Morton					5 Lp	..	10 39 49	13 07 30	13 11 10
12. G. Longworth, G. Bakos					6 Lp	10 36 40	10 39 12	..	..
13. J. B. Oke					4 L	..	..	13 07 52	13 11 26
Other groups									
14. W. Mitchell, C. Hallam	Windsor	5 32	+42 20	...	3 L	10 37 32	..	13 07 51	13 10 58
15. P. O. Parker	Griffin, Ga.	5 37.1	+33 15	298	4 L	..	10 40 27	13 09 02	13 11 15
16. H. B. Beidler	Chicago, Ill.	5 50.4	+41 50	...	5 L	..	10 40 18	13 08 30	13 12 01
17. S. W. Howell, V. Hofer, P. Hannah, E. Jones, K. Cull	Yankton, S.Dak.	6 29.5	+42 53	...	7 Lp	..	10 40 32	13 08 01	..
						M.S.T.	M.S.T.	M.S.T.	M.S.T.
18. J. V. Hodges, G. L. Hodges, G. Thompson, R. J. Harper, M. Worel	Regina, Sask.	6 58.4	+50 26	...	4 L	8 38 18	8 40 36	11 08 06	11 11 41
19. W. P. C. Kinsman	Regina, Sask.	6 58.4	+50 26	...	3 Lp	..	8 40 41	..	11 11 35
20. D. M. Hunten, G. G. Shepherd	Saskatoon, Sask.	7 06.5	+52 08	515	7 Lp	..	..	11 08 13	11 11 09

L — refractor, M — reflector, p — projected image

THE 800-INCH TELESCOPE

By John A. O'Keefe and Donald D. Mears

Recent instrumental developments have opened up the possibility of obtaining, by high-speed photography of occultations or by photoelectric photometry, a degree of resolution in the observation of celestial objects equal to that which would be obtained with an 800-inch telescope. Although this work can best be done with a great instrument, there are many important observations which can only be made with small instruments, since there are severe limitations upon the observability both of eclipses and of occultations.

The new technique was first applied at eclipses to the measurement of the profile of the moon and the structure of the lowest layers of the photosphere.[1] It has revealed that the limb of the sun is extremely sharp; a fact of considerable importance for astrophysical theories of the structure of the sun's atmosphere. Even finer details have been revealed by Whitford's[2] technique of photoelectric recording of stellar occultations, such as a series of stellar diameters measured by Whitford himself; and an appendage, only 0″.02 away from Antares, discovered by Evans[3], at Pretoria, in 1950. Photoelectric studies of occultations yield, however, not only great refinement in detail, but also great precision in measurement; consequently the Army Map Service[4] has employed photoelectric recordings of occultations to measure the distance of the moon and the radius of the earth.

The principle of this 800-inch telescope is very closely related to the principle of the pinhole camera, as described by Rayleigh, in the eleventh edition of the Encyclopedia Britannica. Rayleigh pointed out that for narrow apertures and long focal lengths the pinhole camera has a resolving power equal to that of a lens camera. He was led to the "rather startling conclusion" that the pinhole camera theory suggests a method of constructing a telescope of unlimited resolving power. It is only necessary to make the focal length greater than $2r^2/\lambda$, r being the radius of the aperture, and λ the wave-length of the light. When Rayleigh considered the relevant numerical values of the focal length, however, the problems of practical usefulness appeared insoluble. For example, to get the resolving power of a 4-inch telescope, a length of 5 miles is required. R. W. Wood, who was so expert at getting significant results from optical curiosities, confined himself to quoting Rayleigh *verbatim* on the resolution of a pinhole camera.

There is a sense, however, in which it is true that many observations of solar eclipses and occultations since the earliest times have made use

of the pinhole principle. One side of the pinhole is provided by the edge of the moon, at a stellar occultation. The opposite side, as well as the top and bottom, are missing. This absence of the top and bottom means that we are dealing with something more like a slit than a pinhole; consequently we will not get any resolution, from a single occultation, in a direction parallel to the arcs of the slit; i.e., parallel to the moon's edge. To obtain the resolution parallel to the moon's edge we must make use of a second occultation with a different position angle of the occulting portion of the moon's limb. Again since the opposite side of the pinhole is also missing, the light received is to be regarded as the sum of a large number of parallel slits, of which the last is that next to the moon's edge. As the moon's edge sweeps over the object which is to be examined, these fictitious slits are covered, one by one. By taking differences between the intensities at successive short intervals of time, we can, speaking roughly, undo this process and get back to the intensities produced by the original fictitious slits. The picture here is actually much less simple, because of the phenomena of interference, especially if we try to resolve into very narrow slits; but this is the general principle. In short, from the patterns observed at stellar occultations or eclipses, it is possible to deduce certain features of the original light pattern; and further, the order of size of the detail which can be studied in this way is approximately that which would be resolved by a pinhole camera, in accordance with Rayleigh's theory.

The resolving power of this telescope can be approximately gauged from Rayleigh's formula, if we put in, for the focal length, the moon's distance, of approximately 240,000 miles. The corresponding radius, r, of the aperture, for a wave-length of 1/45,000 of an inch, is 411 inches; the diameter is 822 inches (and hence our title). By the usual Dawes formula, the resolving power, in seconds of arc, should be: $4''/822 = 0''.005$ ⊙ This is evidently about the right order of magnitude, as can be seen from the tracings (figure 1) of photelectrically measured occultations. The steepest part of the drop lasts about $0^s.015$, which, with an average figure of ½ of a second of arc per second of time for the moon's apparent speed near the meridian, corresponds to about $0''.005$.

Coming down from the realm of pure theory to the practical details, the simplest method of using the moon in this way would be to photograph the shadow of the moon on the ground. Because of the faintness of the shadow, this cannot be done at an occultation. It has been attempted several times at eclipses, usually with results of a rather vague and dubious kind, owing to the fact that we have a whole row of pinholes around the edge of the moon, all acting at once.

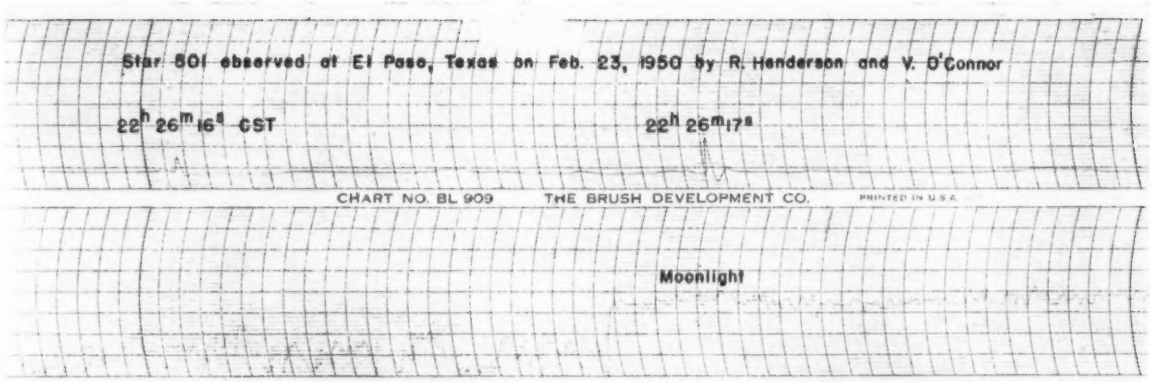
Star 501 observed at El Paso, Texas on Feb. 23, 1950 by R. Henderson and V. O'Connor
22h 26m 16s CST
22h 26m 17s
CHART NO. BL 909 THE BRUSH DEVELOPMENT CO. PRINTED IN U.S.A.
Moonlight

FIG. 1.—Photoelectric observations of a star occultation.

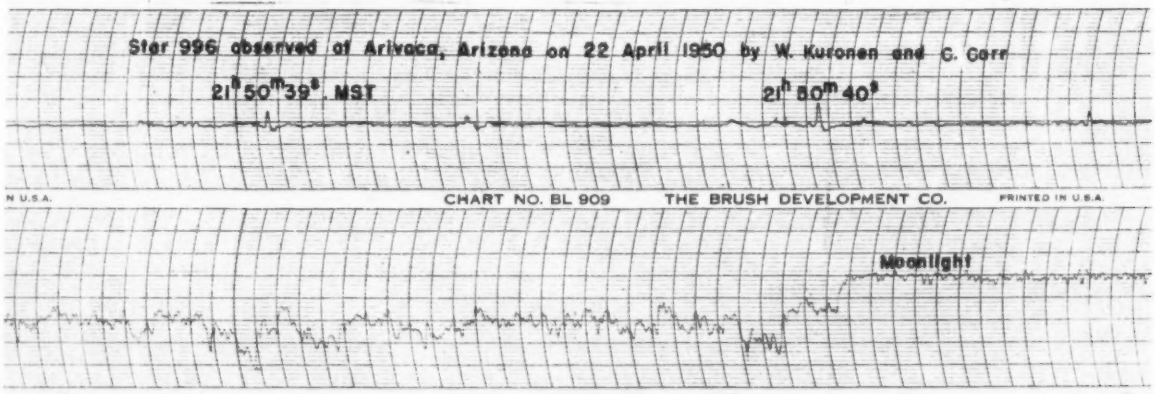
Star 996 observed at Arivaca, Arizona on 22 April 1950 by W. Kuronen and C. Carr
21h 50m 39s. MST
21h 50m 40s
N U.S.A.
CHART NO. BL 909 THE BRUSH DEVELOPMENT CO. PRINTED IN U.S.A.
Moonlight

FIG. 3.—Photoelectric occultation of a double star.

A more effective method is to station an observer in the path of the shadow, with a telescope pointed at the star (or sun) and to follow the change in light by means of a photoelectric cell, or by photography. The photographic method has been successfully applied to eclipses, where there is plenty of light and the relatively low efficiency of the photographic plate is unimportant by comparison with its ability to record both intensity and direction of light at the same time. This is, in fact, the basis of the techniques of Bonsdorff and Lindblad for the measurement of long terrestrial distances by the timed cinematography of total solar eclipses. For a further account of these methods, the best account in English is that by H. Kristenson.[5] We shall be chiefly concerned in the remainder of this paper, with the problems connected with photoelectric observation of occultations.

The design of a suitable instrument for the photoelectric recording of occultations is a delicate job. It is necessary to obtain a measurable amount of current within a time of the order of $0^s.01$. For this purpose, we employed the RCA 1P21 and 931A phototubes, which are commercially available and give excellent response with simple handling. Both tubes incorporate a photosensitive cathode surface, plus a series of electron multiplier surfaces called dynodes. An electron ejected from the cathode by the light is accelerated by a 90-volt potential difference to strike the first dynode. The impact liberates 4 or 5 new electrons, which are accelerated by a second 90-volt drop toward the second dynode. After 9 stages of multiplication, including a final anode acceleration of 45 volts, a total amplification of about one million has been reached.

The problem, in using a cell of this type, is to keep down the effects of irregularities in the flow of electrons. Circuits have been constructed which actually count the individual electrons leaving the first cathode surface; but our problem is rather to smooth out the irregularities, so far as possible. Obviously the mere fact that we are dealing with small numbers of electrons is going to imply some statistical irregularities in the flow of current. Specifically, if, on the average, we are getting 1000 electrons in an interval of $0^s.01$, then, by the usual principles of statistics, we will expect a mean deviation of the square root of 1000, or about 30 electrons, more or less, in any given $0^s.01$; that is, we shall expect the number of electrons to fluctuate between 970 and 1030 electrons per 0.01 second. In absolute values, the spread will increase as the square root of the number; but percentage-wise, which is what counts, it will decrease as the square root of the number of electrons.

One way to beat the game would be to obtain a photocell whose efficiency at the cathode surface was higher. M. Lallemand, at the Paris Observatory, is actively working on this problem, with results which

appear hopeful. Since his cells are experimental, we have stuck to the commercially available cells; but perhaps this line of progress is promising.

A more immediately available approach is to lengthen the time of response of the electrical circuits involved. Very roughly, this means that the current is momentarily stored in condensers, and then allowed to leak out through high resistance in such a way as to steady the flow of current. The time of response is then the time required for the bulk of the accumulated charges in the circuit to leak away. If the time of response is made as long as one second, we shall, roughly speaking, be averaging the number of electrons coming out of the cathode over this time; and we shall get relatively little disturbance due to fluctuations in the numbers; while if the time is one ten-thousandth of a second, the percentage fluctuations will be 100 times as great, other things being equal. For ordinary photoelectric measurements, it is useful to employ the longest response times which are practical. In measuring occultations, however, it is necessary to keep the time of response at about $0^s.01$ or shorter, in order that the lag of the circuit may not affect the measured times. It was Prof. Whitford, at the University of Wisconsin, who called our attention to this question and helped us to get a reasonable solution.

Let us look more precisely at the signal-to-noise ratio for the star alone, ignoring the background. Numerically, it can be shown that we shall expect about 4000 electrons in 0.01 second from a 6th magnitude A-type star near the zenith, using a 1P21 photocell and counting the electrons as they leave the cathode, before any multiplication. Allowing for about one magnitude of extinction, a reddish star, and a half magnitude of light-loss in the telescope, the actual figure is perhaps more like 500 electrons. This corresponds to a variation of about 22 electrons per 0.01 second above and below the mean; it also means a signal to noise ratio of 22. The total spread of the actual oscillations of the pen will then be ⅓ or ¼ of the total displacement remembering that the spread is counted both up and down, and that it exceeds twice the standard deviation by a factor of 2 or 3. Evidently if we go to an 8th magnitude star, and hence reduce our signal-to-noise ratio by 2.5 we will have an ugly looking trace at best, although perhaps a legible one, if there is no background noise.

The most serious obstacle to the observation of faint stars, however, is not the noise produced by starlight but the noise from moonlight. The full moon is 100 million times as bright as an 8th magnitude star. It is therefore a matter of considerable importance to screen it out. It is evidently impossible to observe any stars except the brightest at the moon's bright limb. Again, the altitude of the star is important; at low

altitudes the atmospheric scattering increases the moonlight around the star at the same time that it cuts down the star light. If our telescope is mobile, we can ask the computers to obtain the optimum conditions.[4] In the field, if we have a choice of sites, we can perhaps get clearer skies by moving to the top of a hill. This has the double effect of reducing the haze (and hence the moonlight) and increasing the star brightness. There is often a very considerable change in even a few hundred feet of elevation. Once we have fixed our site, however, it is a matter of instrumental arrangement to reduce the moonlight.

An obvious and effective step is to pass the light of the star through a very narrow aperture. Much photoelectric work is done with apertures as large as 30 seconds of arc. If this could be reduced to 10 seconds of arc, the reduction would, theoretically, strike only at the moonlight. If the preponderant source of noise is the moonlight, as is often the case, this step alone will improve the signal-to-noise ratio by a factor of 3. Since the Airy disk for a 12-inch telescope is only about 0″.67 in diameter we could in theory reduce the aperture much further than 10″.

The obstacles to the modest ambition of using effectively a 10″ aperture are unexpectedly great; and the design of the telescope is largely controlled by the effort to overcome them. The remainder of this paper will be largely concerned with this effort.

The first obstacle to be met is physiological. In many designs of photoelectric equipment, (see figure 2), the star is viewed after it has passed through the aperture by a periscope arrangement which comes under the diaphragm. The periscope is withdrawn to make a measurement, and the starlight then passes on to the photocell. When this arrangement is used near the moon, on a faint star, through the periscope the observer sees the tiny aperture as a bright spot on a black field. Within the spot he must find a still smaller and brighter spot which is the star. The situation is like trying to read a book by a desk-lamp in a dark room; as all the oculists tell us, the glare is blinding. If the star wanders out of the aperture, the observer does not know which way it has gone, and so does not know how to move the telescope to get it back. He is only too likely, as the crucial seconds tick by, to make matters worse by flailing around in all directions.

To meet this obstacle, we have adopted a technique like that used by the spectroscopists. The aperture is drilled directly through a metal diagonal mirror, and the star image is focused on the aperture. Guiding is done on that part of the star image which does *not* go into the aperture. The star is seen as a bright spot, and the aperture as a dark spot on a large uniformly illuminated background. It is very much easier to dis-

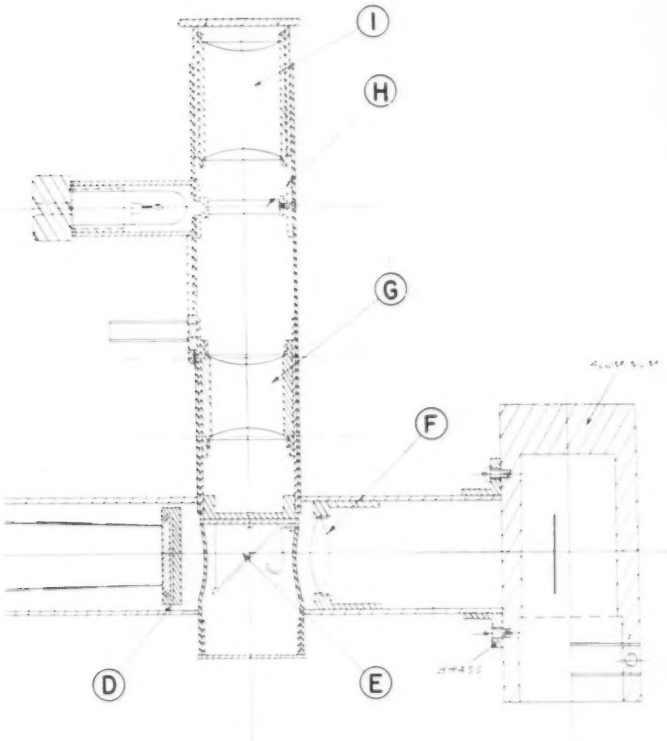

FIG. 2.—Tail components of original occultation telescope. *D*, diaphragm; *E*, reflecting prism; *F*, field; *G*, *véhicule*.

tinguish the star under these circumstances; and of course if it gets out of the aperture one can see exactly how to get it back in. The observers are agreed that this procedure is very much easier to work than the other.

An advantage of the pierced diagonal mirror is that the optics of the periscope train can be simplified. Eyepieces of moderate power can be found whose working distance is great enough so that they can be set up to examine the aperture directly. Under the other system, with the aperture in front of a diagonal prism, it was necessary to have a separate optical element, which the French call a *véhicule*, to catch the image at the focal plane and reproduce it, further back where it can be examined by an eyepiece. This made for an expensive optical train, as well as for an inevitable loss of both width and brilliance in the field.

A second advantage of the pierced diagonal mirror is that the extra current from the moonlight, which increases rapidly in the last few minutes before an occultation, can be balanced out accurately. With the diagonal prism, it often happened that when the prism was withdrawn the flood of moonlight would push the pen right off the paper. Since the prism could not be withdrawn till the last few seconds, the occultation sometimes caught the men still spinning knobs.

A third advantage is that there is no shock caused by withdrawal of the prism. It is very easy to jar a telescope 0.01 inches unless it is very sturdily made; and when moved it does not always spring back.

A fourth advantage is that the star can be watched up to the instant of disappearance. With the diagonal prism, the records often showed that the star wandered out of the aperture between the time when the prism was withdrawn and the instant of the occultation.

Following up the optical path from the mirror, we note that the inside of the tube should be blackened, and, especially, should have a set of baffles. We once tested the blackest paint we could find against a white cardboard baffle; the white cardboard was considerably more effective. Since the light of the moon will be coming down the tube during the occultation at just the angle to bounce off the walls, this matter is a "must". The system of baffles should be prolonged, in the case of a Cassegrain telescope, so that it reaches well up toward the secondary mirror, to cut off light coming from the sky and the moon around the edges of the secondary.

Scattered light from the mirror surfaces themselves is a hazard, especially with aluminized mirrors. One bad form of scattered light, the worst we have seen by far, comes from a sort of bloom on the surface. The French call this *bleuâtre*. It is a bluish tinge, visible only at angles near the true angle of reflection. It is hard to see in ordinary light, since the observer's head tends to block the source of light at small angles; but when the telescope is directed at a point near the moon, the proper conditions are fulfilled, and sometimes the whole mirror has a mottled appearance, like the skin of an orange. It may be produced by dirt on the electrodes during aluminization; or it may be connected with a process of coating for protection.

In addition to being free of scattering, the mirror surfaces must be of good optical quality. This is especially significant in connection with a Cassegrain optical system, where two reflections are involved. We originally specified an accuracy of one wave on each of the mirror surfaces involved, before we realized the precision actually required. This precision was actually met, yet the resulting image was considerably

larger than 10″ in diameter. We were therefore compelled to return the optics for refiguring and tighten the specifications very markedly.

In general design of an optical system, the Cassegrain optics were chosen because of the necessity of having a portable telescope. The physical length of our telescope tube, including the photocell and eyepieces, is only about 4 feet; with Newtonian optics and an equivalent focal length, it would have been about 15 feet. It is not practical to diminish the focal length because this means diminishing the physical size of the focal-plane diaphragm, and raising the magnifying power of the eyepiece. Both of these are difficult to arrange. On the other hand, a 15-foot tube is an engineering problem at every stage of operations, especially where it must be demounted for transportation.

For the mounting of the telescope, we found that the utmost rigidity was essential. One of the critical spots is the spider that holds the Cassegrain secondary. We found that our secondary was resonating to the motor vibrations, and producing an elongated image which resembled an astigmatic image, except that it became round when the motor was turned off. Blotting paper pads at the junction with the tube were used to stop this.

We found that the gearing for the telescope drive and for the slow motions has to be very carefully designed to keep out slow vibrations caused by the wind, in which the telescope bounces back and forth on the teeth of the gearing. Our original mount had a clock drive which ran a gear which was coupled to the declination axis only through the R. A. slow motion. This gave two chances for backlash instead of only one, as in the usual system. We hope to cure these troubles on our new design by making use of the Porter principle of a friction drive, in which the function of holding the telescope in place is discharged by a clutch arrangement, while the function of moving or driving the telescope is discharged by gears which must overcome the clutch friction. In this way backlash in the gearing ought not to lead to shaking in the whole telescope.

Our original mountings (see figure 3) supported the polar head on a steel pipe which was bolted down to one corner of a triangular plate. This arrangement vibrated very badly indeed. The chief vibration was in the triangular plate, although this was ¾ inch thick. The vibration could be much reduced by piling rocks over the triangular plate; but by far the best solution was to bury the whole thing up to the neck, so to speak, in a ton or two of concrete.

Since, in the field, the observer does not have the benefit of elaborately designed stepladders to sit on, and since such arrangements are always

FIG. 3.—The original mounting. This is NOT the 800-inch telescope.

uncomfortable anyway, it is evident that there is a lot to be said for a fixed eyepiece arrangement. This is especially true in observing faint stars, where the star, if lost, cannot be recovered in the finder after the moon has come within a degree or so. There is nothing for it but to catch the star early in the evening, and hang on to it up to the moment of occultation. This is very hard on the observer at best, especially because there is a certain amount of emotional tension—what Prof. Whitford calls "buck fever". After all, you don't get more than about one shot a month; and you don't want to miss it. It follows that the human engineering should not be ignored.

Even more sensitive than the observer's neck, however, to the odd twistings and turnings of the telescope is the cable that leads from the photocell to the power supply and to the ground. The cable carries about 900 volts, distributed over about a dozen separate wires. If it gets kinked too often, there will be leakages and failures. We originally placed the power supply on the ground and let the cable reach up to the eyepiece; but here again we see the advantage of a fixed eyepiece, which would reduce the motion between the photocell and the power supply. To see the results of these changes compare figure 3 and figure 4.

Our power supply for the photocell consisted of a black box full of 45-volt hearing aid batteries. From this a cable led to the amplifier.

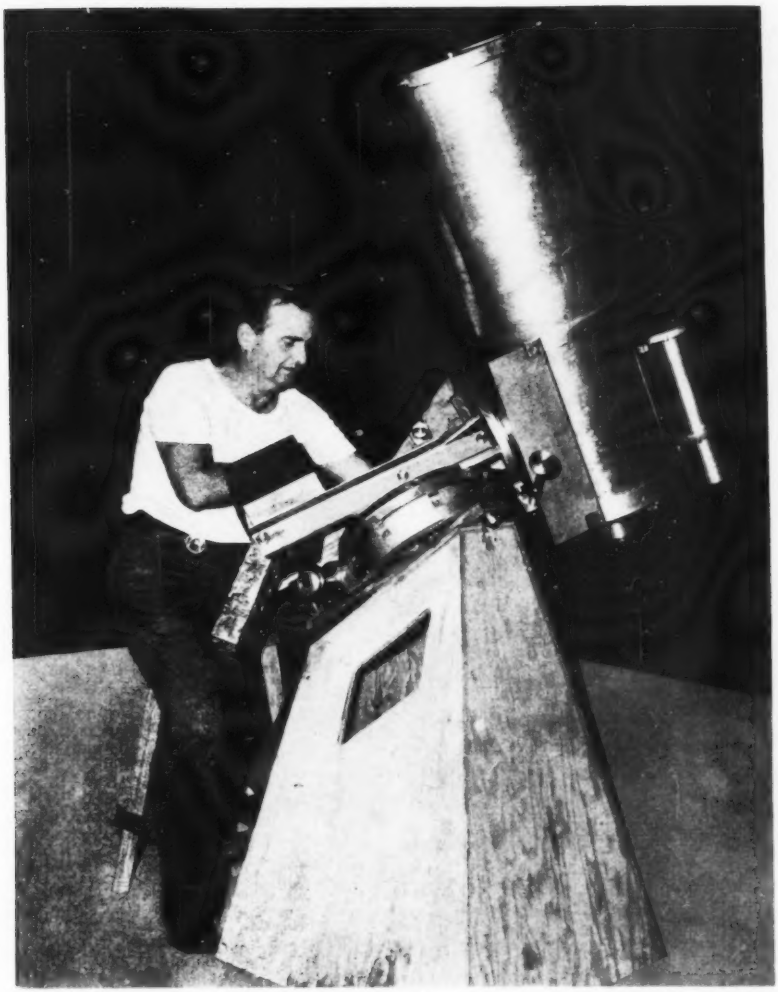

FIG. 4.—Mr. John Myslak, with the Springfield mounting. This is NOT the 800-inch telescope. The eyepiece and motor are not shown.

carrying the current from the anode. In the plug of the lead-in cable, there is a one megohm resistance, which combines with the input impedance of the amplifier to yield 10 megohms. The output of the photocell is of the order of 10^{-7} amperes, and it is nearly constant up to

a resistance of the order of 10 megohms; hence it follows that about one volt is developed across the terminals. With a measured distributed capacity of about 0.007 microfarads, the time constant of the circuit is 0^s.07.

The amplifier used was a standard Brush amplifier, Catalog No. BL 913. The recorder was a Brush recorder, Catalog No. BL-202. Both of these items stood a lot of transportation including banging over wadis in Morocco and lava fields in Colorado, with a minimum of trouble. We took the precautions of screwing the equipment firmly down over rubber cushions in the trucks, and cushioning all parts not screwed down with foam rubber while in transit. Occasionally the points of the pen became clogged with dirt. Since the points are too fine to admit a hair, it is difficult to clean them. Mr. Robert Kekoa discovered that if a lighted cigarette is touched to the pen, the water boils and drives out the obstacle. We believe that we saved a lot of headaches by using inking recorders in preference to photographic recordings.

The results obtained with the equipment which we first built, are shown in figure 1. It will be seen at once that it is relatively easy to determine the instant of the occultation from these tapes with an error not exceeding a hundredth of a second (the interval between vertical arcs is 1/25 of a second). It can thus be effectively employed for the recording of occultations in conjunction with the worldwide programme for the study of the lunar motion by means of occultations. It is almost too good for the purpose; since all observations have hitherto been visual, the tables of the moon contain the personal equations of the observers. The photocell has a negligible lag; and in consequence it will be necessary to use some caution in combining results from it with results from human observers.

In addition, it is possible to get the parallax of the moon by observing the occultation of a given star from two widely separated points. For an accurate determination, the two points should be so chosen that the same point of the lunar edge produces the occultation at both points. This technique has been worked out both by the Army Map Service and by the Tokyo Astronomical Observatory. The Tokyo results are not yet published; the Army Map Service results, based on only four occultations, tended to confirm Brown's value of the lunar parallax.

In the course of reducing the Army Map Service results, it was noticed that the figure of the earth is also involved. This is because the process of observing an occultation at two widely separated points amounts to timing passage of the moon's shadow over a known course. The course in this case is the earth's surface, which is moving. Thus the timing gives

an indication both of the speed of the shadows and of the speed of the earth's rotational motion. Now the earth's angular velocity is known and constant to a few parts in a hundred million; but the linear velocity is the product of the angular velocity by the radius of the parallel; and the radius of the parallel is known only to about one part in 30,000 or less. The speed of the shadow and the speed of the earth's surface are quite comparable; thus both really enter the problem. Since an increase in the number of unknowns tends to weaken a solution, this discovery meant that with the small number of measurements so far made, it is not possible to get a reliable solution either for the earth's radius or for the lunar parallax. Nevertheless, if we throw all the uncertainty into the earth's radius, we get a value of $a = 6{,}378{,}440 \pm 160$ metres which is a respectable result from only four stars, and indicates that the method has promise. It is particularly interesting because it differs from many previous measures of the earth's radius in that it does not depend upon an extrapolation of the radius of curvature made in one place.

An unexpected, but fortunate result was that the star 228 B Aurigae, No. 996 of the Zodiacal Catalog, was found to be double, on three tapes taken on April 22, 1950. It is a peculiarity of occultation measurements of this kind that they do not give either the separation or the position angle of the pair, they give only the projection of the separation on a line perpendicular to the moon's limb at the position angle of contact. The position angle of contact for all three measures of 228 B Aurigae was 255°; the separation, resolved along this direction, was 0″.05. One of the tapes showing the double drop is reproduced in figure 5.

The future of this method looks bright. It is a field which the great telescopes can never monopolize; many of the most important occultations are simply invisible at the great observatories. It appears to be a most hopeful field for the amateur who is willing to gamble a little in the hope of striking it rich. Even if the amateur never gets anything spectacular, his lists of photoelectrically observed occultations will be most thankfully received by the lunar theorists.

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UNGAVA (CHUBB) CRATER AND GLACIATION*

By J. M. Harrison†

In the course of a geological reconnaissance of northern Ungava made by airplane in the last half of July and the early part of August 1953, the writer spent six days camped on the large lake about one and a half miles north of the Ungava Crater.‡ Parts of these six days were spent at the crater. The crater has been described by Meen in various publications (1, 2, 3) and he concluded that it was formed by impact or explosion of a large meteorite and that "No sign of glaciation was seen on or around the crater itself" (1, p. 177). From some of Meen's illustrations it had seemed to the writer that the crater, however it was formed, was pre-glacial and, if so, some of Meen's data required modification. As a result of the examination made last summer the writer disagrees entirely with Meen's opinion on glaciation, but he agrees that the impact or explosion of a meteorite appears to be the logical explanation for the crater.

It is the purpose of this paper to present the evidence for continental glaciation of the crater, and to indicate some of the revisions necessary in the published accounts. It should be made clear at the outset that the writer has had no previous experience with such craters and that observations were limited to geological data.

Late in August 1953, the area about the crater was photographed on large scales by the Royal Canadian Air Force at the request of the Dominion Observatory. Officers of the Observatory are now making a study of these photographs.

Evidence for Continental Glaciation

1. The mosaic of photographs (figure 1) shows clearly that the rim of the crater was grooved and striated by a continental ice sheet. Note especially the crag-and-tail structure on the middle eastern part of the rim showing ice movement from south-west to north-east.

2. Glacial striae, approximately parallel with the major grooving, were noted at several localities around the rim, and glacially polished surfaces are common on rock outcrops of the rim.

3. The shapes of the hills show the whale-backed symmetry com-

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†Geological Survey of Canada.

‡From its geographic location the crater has been named the "Ungava Crater" by the Canadian Board of Geographical Names.

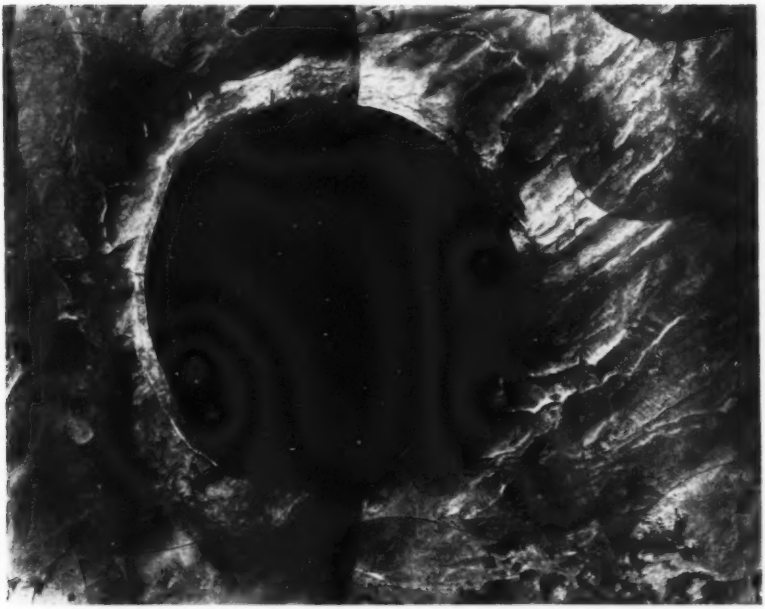

FIG. 1.—Mosaic of photographs of Ungava Crater. Scale 1 inch = 4180 feet.

monly formed by advancing ice and also indicate a movement from south-west to north-east. (1, Pl. IX, Fig. 14)*

4. Perched boulders are common around the rim of the crater, a feature that is characteristic of glaciated areas. Some are so delicately balanced that they can be toppled with a slight push (1, Pl. VIII, Fig. 11); others that are several tons in weight rest on pebbles and cobbles no more than four inches in diameter. If these large boulders had been dropped as a result of the explosion, they would surely have smashed the supporting pebbles or have rolled to a more stable position.

5. Well-rounded glacial erratics of material foreign to the crater area are fairly common. Meen attributed these to a dyke of diabase that probably "cut across the granite . . . near what is now the south rim, and was fractured by the blast, raised and ejected along with the granite." (1, p. 177.) Neither Meen nor the writer found the slightest trace of such a dyke, although several dykes can be seen on air photo-

*These bracketed figures refer to photographs used by Meen to illustrate the crater in the various publications; the first figure refers to the numbered reference at the end of the paper.

graphs of country a few miles south and south-west. Some of these are known to consist of diabase. One boulder of such rock was seen in a perched position on the rim and several others were found on the inner slope; all are well-rounded and typical of glaciated areas. Similar boulders were found more than 100 miles from the crater.

6. Many of Meen's radial valleys (1, Fig. 6, p. 174, and p. 175) are partly filled with boulder till and in some the till is piled higher at the inner end than the outer. Those that are essentially parallel to the direction of glacial movement show the U-shaped section characteristic of glaciated valleys (1, Pl. IX, Fig. 15). These valleys do not radiate outwards from the centre of the crater, as illustrated by Meen (1, Fig. 6, p. 174) but intersect the inner rim at various angles. This can be seen on the mosaic (See figure 1) where it will also be noted that the main valley, in the north-east, has the shape of a flat "S". This shape is due to local accumulations of moraine material on the flanks of the valley. Those valleys that lie across the direction of glaciation are, if present, mainly filled with boulder till. Some valleys transverse to glaciation are sharply defined and either mark small faults or are the result of ice plucking.

7. The top of the rim, especially the north and south parts, are covered with a mantle of typical boulder drift (1, Pl. VIII, Fig. 10; and 3, p. 25, p. 26).

8. The lowest point on the rim is the deeply incised valley on the west side of the crater (see figure 1). Its floor, about 180 feet above present lake level, is covered with well-rounded boulders and is characteristic of abandoned stream beds. It was probably the outlet to the crater lake when the bowl was filled with meltwater from the receding glaciers, in which case the crater lake was once part of the normal surface drainage and the presence of fish in it is no problem.

9. South from the south rim a large fan of glacial outwash and till slopes downward from the top of the rim.

10. The inner slope of the crater on the east side is composed of finer glacial till and gravel. Numerous erratics are present, especially at lake level. This could only have been placed there by glacial action after the crater had formed.

11. The area about the crater itself is covered with rounded boulders of glacial origin mixed with some angular, frost-heaved fragments of bedrock, and is the surface to be found over much of the barren lands (3, p. 11, p. 14, p. 16). If such material near the crater is "made up of fragments which have been thrown up from the crater" (1, p. 176), then much of the barren lands has been so littered.

General Considerations

Because the crater has been glaciated, any search for identifiable fragments of meteorite is almost certain to be fruitless. The ripples of rock north of the crater rim (1, p. 176 and Fig. 6, p. 174) may actually be due to the pressure of an explosion, but they do not continue completely around the crater. On the west side, if they were present, they now remain only as isolated humps that are glacial remnants; on the south they are covered by glacial outwash; and on the east their shapes have been so modified by glacial erosion and deposition that they are not readily recognizable. The radial "rifts," if they were such, have been so modified by glacial action that it is dangerous to conclude anything from them.

Time did not permit a detailed check on Meen's observations regarding jointing in the granitic gneiss of the rim (1, p. 175). However, joints that dip outwards at low angles were noted at several localities, suggesting that the rock was lifted and tipped outwards. Radial and peripheral jointing were also noted, but were locally, at least, modified by the presence of strong foliation in the gneiss. In this region of extreme frost action it is difficult to be sure that fracturing is not due to that effect, rather than to an explosion.

Meen reported (2, p. 57) magnetic attraction at the north-east side of the crater where later he reported (3, p. 24) a magnetic anomaly that gave "positive evidence" of a buried meteorite. Similar magnetic attraction was noted by the writer at the south and south-west part of the rim and was attributed to magnetite that can be seen in the granite gneiss.

Conclusions

Inferential and negative evidence indicates that the crater was formed by the impact or explosion of a large meteorite. Glaciation has obscured or destroyed much of the evidence and it is impossible to fulfil the requirements set up by Healy, LaPaz, and Leonard (4) to establish proof of origin by meteorite. The strongest indications are the fact that the rim rises to 500 feet or more above a plain of ancient granitic gneisses and that the crater is nearly round, which suggests explosion rather than impact. No other such lake has been reported among the myriads that dot the Canadian Shield. There exists no vestige of volcanism in this area since some time hundreds of millions of years ago, and even if the crater were due to volcanism, the high rim would be formed of ejectamenta, not of the granite bedrock of the plain. The gneissosity and foliation of the granite trends generally north and dips are steep; they show no re-

lation whatever to the configuration of the crater. Nor was any evidence found of an easily eroded intrusive plug, and in any case a raised rim would not be expected. It is extremely unlikely that it could have formed by melting of a buried remnant of glacier ice, as was implied by Hoffleit (5). In the first place the rock is granite, glacially polished, and the rim itself was glaciated. The writer can think of no means by which the ice could have worked down more than 800 feet below the level of the plain (3, p. 20) into granite, nor would it account for the raising of a concentric rim 500 feet or more above the plain.

If the crater is pre-glacial, and the writer considers the evidence overwhelming for such a dating, why was the crater not filled with glacial debris? When conditions became propitious for the formation of continental ice, the crater lake froze and the upper part of the crater filled with snow and eventually ice, and so formed a smooth base for the continental ice to slide on. The rim, standing an average of about 300–350 feet above the plain, would act as a powerful deflector to the even flow of the ice and most of the flowage was around, not over the crater. Locally, gouging of the rim did occur and much glacial debris was dropped on the north-east or lee side of the crater. Some was deposited in the crater itself, as shown by the rounded boulders included in the talus slope and the till on the inner slope at the east side, but most was carried beyond it.

No date can be given for formation of the crater but it must have been formed before the last advance of continental ice in this area.

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VARIABLE STAR NOTES

American Association of Variable Star Observers

By Margaret W. Mayall, *Recorder*

The results of the request we made for more observations of faint stars have been very gratifying. Many of the A.A.V.S.O. members have been sending observations down to the 14th, 15th, and even 16th magnitudes. A few years more of such observations should tell us a great deal about the minima of some of the fainter variable stars on our programme. Notes about some of the most interesting variables follow.

U Geminorum-Type Variables

020356 UV Persei. No maximum observed during the year. The star has been between 15th and 16th magnitudes, according to Thomas Cragg and Claude Carpenter.

060547 SS Aurigae. Four maxima were observed during the year, as follows: 4418, 11.0; 4495, 10.8; 4619, 11.5 (one observation by Gunnar Darsenius); and 4690, 10.6. The widths of the maxima, at the 13th magnitude, the half-way point between maximum and minimum, were 6 days, 12 days, not more than 12 days, and 13 days, respectively.

061115 CZ Orionis. The following maxima were observed in 1952 and 1953: 4020, 11.8; 4047, 13.0; 4073, 12.0; 4100, 11.7; 4125, 12.4; 4269, 12.4 (a single observation by Joseph Meek); 4308, 12.2; 4331, 12.0; 4365, 12.2; 4390, 12.0; 4409, 12.4; 4439, 11.6; 4470, 11.6; 4501, 12.0; 4632, 12.8; 4667, 12.8; 4707, 12.2. The mean interval between maxima is 30 days, varying from 19 to 40 days.

074922 U Geminorum. In May a maximum was observed, 4505, 9.2, the only one during the year. The interval between maxima is listed in the catalogues as 97 days.

080362 SU Ursae Majoris. Most of the maxima of this variable are very narrow, with rapid rise and fall, but at times the star remains bright for some days. This occurred in the maximum observed about the end of April 1953. The variable was 12th magnitude or brighter from 4490 to 4501. Maxima were observed on the following dates: 4416, 11.7; 4441, 12.7; 4454, 11.5; 4464:, 12.4; 4476, 12.0; 4496, 11.7; 4538:, 12.5; 4558:, 12.5; 4612:, 12.6; 4627, 12.2; 4637, 12.1; 4656, 12.3; 4666, 12.0; and 4680, 12.0. A colon after the date indicates that the maximum was determined from a single observation by a reliable observer.

082953 SW Ursae Majoris. No maximum has been observed since December 1943.

094512 X Leonis. The following maxima were observed: 4407, 12.0; 4447, 12.5; 4477, 12.9; 4499, 12.1; 4529, 12.0; 4664, 12.0. Normal minimum is about 15.7 magnitude.

184137 AY Lyrae. A maximum was observed on 4597, magnitude 12.1. The star was brighter than 13.5 from 4596 to 4609, a very broad maximum.

195109 UU Aquilae. Three maxima were observed: 4554, 11.5; 4602, 12.0; 4663, 11.2.

213843 SS Cygni. Seven maxima were observed during 1953. The light curve of SS Cygni will be given in a future number of these notes.

220912 RU Pegasi. During the last two years (1952–53) seven maxima have been observed, as follows: 4066, 10.7; 4166, 10.7; 4268, 10.5; 4334, 10.5; 4404, 11.1; 4461, 10.9 (a single observation by Peltier); 4612, 10.5.

R Coronae Borealis-Type Variables

054319 SU Tauri. There is no sign of activity in this star. Its mean magnitude remained at about 9.6 throughout the year.

145971 S Apodis. A minimum started in the middle of November 1952, reached 13½ magnitude in early April. By the first of October 1953 it had brightened to 10th magnitude, its normal maximum brightness.

154428 R Coronae Borealis. In December 1952 R Coronae Borealis was down to 11th magnitude. After an irregular rise, it was back to normal 6th magnitude in April 1953, where it has remained ever since.

191033 RY Sagittarii. Irregular activity is increasing in this star, and there is a two-magnitude scatter of observations. Perhaps we will have a minimum in 1954.

Z Camelopardalis-Type Variables

005840 RX Andromedae. This variable has been almost constant at 11.6 magnitude throughout 1953.

020657a TZ Persei. Varied between 12½ and 15 during the year. The star is faint much of the time and more observations with large telescopes are needed.

054705 CN Orionis. This star was neglected in 1953. It varies between 12 and 15.

081473 Z Camelopardalis. A fairly regular period of about 20 days and a range from about 10½ to 14½ magnitudes was observed until November 1953, when it became nearly constant at 11.6 magnitude.

195377 AB Draconis. This star has been very active throughout the year. It varies from about 12th to 15th magnitude.

Flare Stars and Other Peculiar Variables

013418 UV Ceti. This interesting flare star has shown very little activity during 1953. On J.D. 2434594 de Kock observed a rise from 12.4 to 11.7, and on 4697 Cragg observed a drop from 11.8 to 12.3. UV Ceti, like AE Aquarii and the other flare stars requires a method of observation very different from the more slowly varying types of variables. It should be watched for a period of at least half an hour at a time, and longer if there is any indication of activity. In 1952, the A.A.V.S.O. observed two flares of this star: on 4330 Cragg watched it drop from 10.4 to 12.2, and on 4367 de Kock watched it rise from 12.4 to 11.4 and then fade to 12.6.

052801–Orionis. This star, known as "Wachmann's Forgotten Star," was observed on three nights by Thomas Cragg, but no activity was seen.

203501 AE Aquarii. This star was a very disappointing object during 1953. Very seldom was it really constant, but the variation amounted to only a few tenths of a magnitude. On 4619 Cragg observed what might have been the end of a flare. On 4650 Cyrus Fernald, Clinton Ford, and Curtis Anderson observed it rise to 10.3 and then drop back to 11.4; and on 4693 Fernald observed a drop from 10.4 to 11.0. Monsieur Lenouvel of the Observatoire de Haute Provence observed a beautiful flare photoelectrically, on the night of the 8th of August. It is to be reported in the *Comptes Rendus*.

SEMI-REGULAR VARIABLES

013238 RU Andromedae. This variable is in need of more observations. It is catalogued as an ordinary long period variable with a period of 237.48 days and a range of 5 magnitudes. Since about 1940, the light curve has changed form and at times the range of brightness is less than one magnitude. During 1952 and 1953, the period seems to be fairly constant and the magnitude varies from about 11.2 to 12.6.

115158 Z Ursae Majoris. The descending branch of the light curve varies in shape from epoch to epoch. A maximum of 6.7 was observed on 4335: on 4370 it was magnitude 7.8, and on 4405 it was 7.0, again nearly maximum brightness. The next epoch contained two minima, the first one 70 days before the normal minimum, and of equal magnitude, about 8.4.

Nova Search Programme:

During October and November 1953, reports came from the following 10 observers. Listed for each observer is the month the observations were received, the area observed (in italics), the number of nights the region was checked, and finally the limiting magnitude.

ADAMS, ROBERT M., Oct.–*1*, 2, *16*, *17*: 2, 8; Nov.–*1*, 2, *16*, *17*: 2, 8.

DARSENIUS, GUNNAR O., Oct.–*Dome*: 2, 2; *16*, *17*: 6, 6; *16*, *17*: 1, 5; Nov.–*Dome*: 1, 2; *16*, *17*: 3, 6.

°DIEDRICH, DELORNE, Oct.–*Dome*: 1, 2; *94*: 1, 6; *94*: 2, 5; Nov.–*94*: 3, 6.

°DIEDRICH, GEORGE, Oct.–*Dome*: 6, 2; *78*: 7, 6; Nov.–*Dome*: 5, 2; *78*: 7, 6.

°MAHER, JAMES, Oct.–*Dome*: 1, 2; *59*: 13, 4; Nov.–*50*: 3, 4.

MAYRON, BART, Oct.–*24*: 8, 6; *24*: 2, 5; *24*: 1, 4.

°RICK, J. J., Oct.–*79*: 4, 5; *79*: 6, 4; Nov.– *79*: 4,4.

°RICK, LOUIS, Oct.–*Dome*: 10, 2; *18*: 6, 5; *18*: 4, 4; *63*: 12, 5; *63*: 1, 4; Nov.–*Dome*: 10, 2; *18*: 9, 5; *18*: 1, 4; *63*: 10, 5; *65*: 6, 5.

ROSEBRUGH, DAVID W., Oct.–*Dome*: 4, 3; *1*: 2, 4; *34*: 1, 4; Nov.–*Dome*: 6, 3; *34*: 5, 4.

SMITH, FRANKLIN W., Oct.,–3, *4*: 6, 6; Nov.–3, *4*: 10, 6.

°Black River Astronomical Society

Observations received during October and November, 1953: In October we received 6,267 observations, and in November 4,773, making a total of 11,040 from 84 observers during the two months, as follows.

Observer	October		November		*Observer*	October		November	
	No. Var.	*No. Ests.*	*No. Var.*	*No. Ests.*		*No. Var.*	*No. Ests.*	*No. Var.*	*No. Ests.*
Abbey, Leonard B.	3	3	...	...	Kastin, Harold	7	23	9	16
Adams, Robert M.	76	201	73	174	Kelly, Frank J.	12	12	10	10
Alvarez, Hector	...	...	4	4	de Kock, Reginald P.	143	757	142	623
Ancarani, Mario	29	56	28	53	Koons, L. Donald	31	34	31	40
Anderson, Curtis E.	129	327	104	159	Kuenzi, Edward W.	11	58	15	81
Archer, S.	66	108	...	...	Lacchini, G. B.	6	42	...	...
Aronowitz, Charles	28	179	28	115	Lackany	1	2	...	...
Behar	2	4	4	13	Lizotte, Eugene A.	28	68	19	31
Beidler, Herbert B.	20	33	18	29	Lofberg, Alan	1	3	...	...
Bonilla, Tony	11	26	...	...	Lonak, Eugene	3	44	...	...
Boutell, Hugh G.	5	15	6	30	Maran, Stephen	...	...	4	7
Buckstaff, Ralph N.	18	24	21	31	Mebius, William G.	...	...	5	7
Calamaras, Helene	...	...	4	4	Miller, William A.	40	41	13	14
Carpenter, Claude B.	58	79	65	92	Montague, Allen C.	46	68	7	7
Carrington, Tucker	4	9	...	...	Oravec, Edward G.	77	346	115	335
Chandra, Radha G.	25	29	...	...	O'Sullivan, W. H.	14	16	7	14
Chapman, Gary	2	2	...	...	Overbeek, M. D.	65	150	...	...
Charles, Donald F.	...	...	18	19	Parker, P. O.	37	37	41	41
Chester, Bryant	11	11	7	7	Parko, Joseph E.	2	2	4	4
Cragg, Thomas A.	240	266	321	395	Paulton, Edgar M.	5	5	1	1
Cuevas, Charles	...	...	3	3	Pearcy, Robert E.	9	9	7	7
Dafter, Rosina	...	...	5	30	Peltier, Leslie C.	58	240	54	220
Darsenius, Gunnar O.	39	236	32	110	Peter, Hermann	26	618	...	...
DeGennaro, Edward	...	...	1	1	Pridmore, Antoinette	...	...	8	16
Diedrich, DeLorne	2	4	2	6	Renner, C. J.	243	280	227	227
Diedrich, George	5	14	8	20	Rick, Louis	3	5	3	3
Escalante, Francisco	59	64	...	...	Rizzo, Patrick V.	36	87	39	82
Estremadoyro, Gustavo	...	...	1	1	Robinson, James C.	7	9	10	20
Fawzi	1	1	...	...	Rosebrugh, David W.	16	118	19	95
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					Wyckoff, Jerome	30	50	26	39
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A.A.V.S.O. Headquarters
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Cambridge 38, Massachusetts
December 1953

NOTES AND QUERIES

The Spectra of Visual Double Stars

Considerable literature has been written about the spectra of visual double stars since 1920–21, when I first worked in this field at the Lick Observatory (*P.A.S.P.*, vol. 33, p. 213, 1921; *Lick Obs. Bull.*, no. 343, completed Nov. 1921, issued Jan. 1923). The principal conclusions on the subject may still be summarized, however, thus:

(1) If either component of a visual binary is a main-sequence star, the spectral class of that component is generally the same as the spectral class of a single, main-sequence star of the same absolute magnitude; hence, if both components are main-sequence stars, the spectral class of the secondary is normally *later* than that of the primary, the difference in spectral class between the components being greater, the greater their difference in absolute magnitude.

(2) If both components are giants, the spectral class of the secondary is almost always *earlier* than that of the primary, the difference in spectral class between the components being, with few exceptions, greater, the greater their difference in absolute magnitude.

(3) If the primary is a giant or a supergiant and the secondary is a main-sequence star, the spectral class of the primary may be anything from class B to class M, that of the secondary being whatever is normal for its absolute magnitude; in this case also, the spectral class of the secondary is usually *earlier* than that of the primary; moreover, if the spectral class of the primary is earlier than class G, the difference in spectral class between the components is commonly small.

There is some observational evidence that, if any disparity exists between the spectra of the components of visual binaries on the one hand, and the spectra of single stars of the same absolute magnitudes on the other, the difference in spectral class between the components, particularly if they both belong to the main-sequence, is somewhat *less* than that between single, unrelated stars of the same absolute magnitudes; in other words, the components are more nearly alike spectrally than are single stars of the same intrinsic luminosities. If the components are of coeval origin, this conclusion is, perhaps, what might naturally be expected on *a priori* grounds.

Frederick C. Leonard
Department of Astronomy
University of California
Los Angeles.

INVESTIGATIONS OF INTERSTELLAR HYDROGEN BY RADIO TELESCOPES

Radio telescopes, operating at a frequency of 1420 megacycles (or a wave-length of 21 cm.), are gradually building up a picture of the distribution and motion of hydrogen in our galaxy, and even beyond in our nearest neighbours, the Magellanic Clouds (*Sc. Amer.*, Dec. 1953). Gas near hot stars glows and can be photographed; gas far removed from bright stars is more difficult to detect. The prediction that it should be possible to detect hydrogen atoms far from bright stars was first made by the Dutch astronomer van de Hulst in 1944. In March 1951 Ewen and Purcell of Harvard were able to detect the radiation from this so-called 21-cm. line of hydrogen. This was confirmed within three or four months by Oort in Holland and by Christiansen and Hindman in Australia (this JOURNAL, vol. 47, p. 150, 1953). The frequency giving the most intense signal is not always exactly 1420 megacycles. The deviation is interpreted as due to a Doppler shift resulting from the relative motion of the observer on the earth and the hydrogen cloud. As many as three or more hydrogen signals at slightly different frequencies have been detected in one direction by the Dutch astronomers; it is inferred from this that the radio telescope has picked up radiation from several clouds of hydrogen in this direction, the clouds moving at different speeds. By analysing the intensities of the signals in different directions, the Dutch astronomers have been able to plot the distances, positions and general shapes of the hydrogen clouds, and have in this way detected a spiral arm structure in our galaxy.

The spiral structure was first shown by Morgan, Osterbrock and Sharpless of Yerkes Observatory, from photographs of H II regions in the neighbourhood of the sun. Further evidence is being compiled by Münch and others at the Mount Wilson and Palomar Observatories using the coudé spectrograph of the 200-inch telescope (*P.A.S.P.*, vol. 65, p. 179, 1953). The spectrograms of distant stars in the galactic longitude region 65° to 130° show interstellar lines with two components of comparable intensities. The separation is interpreted as due to differences in the radial velocities of two gas clouds between the observer and the star. These correspond to the structural features found by the radio workers and by Morgan and his co-workers.

The first evidence of 1420-megacycle radiation from beyond our galaxy was found by the Australian radio astronomers this summer; the hydrogen radiation was picked up from the Large and Small Magellanic Clouds. The Clouds were found to be revolving around one another, and to be moving away from us. Although the Small Cloud is almost free of dust and the Large abounds in dust, the two were found to have about

the same amount of hydrogen. Certainly the 1420-megacycle radio telescopes are giving us a new picture of the universe.

R. J. N.

The Rotation of Mars

Mars is the only planet whose period of rotation can be obtained with high accuracy. In spite of this there has been no determination of the period since 1886 until recently when Joseph Ashbrook critically examined the question (*A.J.*, vol. 58, p. 145, 1953). Ashbrook rejected the results dependent on drawings as being unreliable. Early observations used in the determination of the period include the timing by Maraldi in 1704 of four transits of Titanum Sinus, and one observation of Sinus Meridiani by Sir William Herschel in 1783. The final value of the sidereal period of rotation of Mars, principally using central meridian transits of 1877 to 1952, is 24h. 37m. 22.6679s. ± 0.0026 (m.e.). The value used by the American Ephemeris and Nautical Almanac in computing the physical ephemeris of Mars is 24h. 37m. 22.6542s. The value of the mean error ± 0.0026s. represents a 25-fold improvement in accuracy. The author points out that observations at the coming close opposition in 1956 may lead to the detecting of irregularities in the rotation of Mars analogous to the irregular changes in the length of the terrestrial day.

R. J. N.

National Observatory Planned in United States

The first American national observatory is being planned; it would be jointly run by several institutions and would probably be located in the south-western United States. Astronomers have set up a committee to co-operate with the National Science Foundation in planning the co-operative observatory.

The location and the size of the telescope are not yet settled. It is agreed that a site in the south-west would give the largest number of clear nights with good seeing. Opinions vary concerning the best size for the telescope. It is expected that the telescope would be used principally for photoelectric observations. The sizes advocated vary from 50 inches down to 36 or 20 inches. Astronomers are submitting their recommendations to Dr. John Irwin who is chairman of the committee.

R. J. N.

The Atlantic Weather Ships

For a number of years 25 ships have been maintained in the North

Atlantic by fifteen nations to obtain information on weather conditions for long-range weather forecasting and atmospheric research. Fourteen of these ships have been supplied by the United States. Washington has announced that its ships will be withdrawn from this service, for it is felt that the benefits are not commensurate with the cost. However, airlines, steamship companies and professional meteorologists do not agree and will try to obtain the information in other ways.

R. J. N.

ASTRONOMISCHER JAHRESBERICHT

The Editor has received from the Astronomischen Rechen-Institut, Heidelberg, volume 50 of this annual German publication which indexes all astronomical literature published during the year 1950 and gives a brief abstract of each paper. The price is DM 750.

J. F. H.

REVIEW OF PUBLICATIONS

Stars in the Making by Cecilia Payne-Gaposchkin (The Harvard Books on Astronomy Series). Pages xii plus 160 plus 67 plates; 6¾ × 9½ in. Cambridge, Harvard University Press, 1952. Price $5.50.

As we look up into the heavens we see almost exactly the same features that were seen by mankind thousands of years ago. Even the largest telescopes show no major changes in the heavens. But modern astronomers have never been willing to accept a static universe. They have always wondered if and how stars and systems of stars change over millions and billions of years. Until recently the study of stellar evolution has been practically impossible. But in the last fifteen years, thanks to the rapid progress of astronomy, this study is no longer impossible, even though it is still extremely difficult. The layman will probably be puzzled to know how it is possible at all to tell how stars and systems of stars change in billions of years when they have been observed for only a few thousand. To find the answer to this question, he should read this stimulating new book. *Stars in the Making* is the newest of the excellent series known as *The Harvard Books on Astronomy*, partly disguised from previous ones by an entirely new format.

The author views the whole history of the universe as a vast drama, and this metaphor is extended, very effectively, into the more detailed discussions. The book is divided into three distinct sections. In the first, entitled "The Players", the reader is introduced to the various kinds of stars, the dust, and the gas which are the actors in the drama. The next section, "The Scene", describes how the players sometimes group themselves into larger units such as double and multiple stars, star clusters, and finally vast galaxies. These two sections are really introductory to the main theme which is presented in the final part, aptly called "The Drama". It outlines the author's view as to how individual stars and systems of stars have behaved in the past, and how they are likely to behave in the future.

The drama, as outlined, has not of course been verified completely by theory and observation. Many of the main features have been tested to some extent and many astronomers will accept the author's interpretation. Other features, still unverified, will perhaps not be accepted by astronomers who may have their own interpretation. But it should be emphasized that the picture presented in this book is that by an excellent astronomer who is well acquainted with all the astronomy which she discusses. It is therefore a book deserving widespread attention. Mention should be made of the very fine collection of photographs included at the end of this book.

J. B. O.

MEETINGS OF THE SOCIETY

AT TORONTO

April 21, 1953—The meeting was held in the McLennan Physics Laboratory. The Second Vice-President, Mr. L. H. Clarke, was in the Chair.

On a motion by Mr. F. L. Troyer By Law II was suspended and the following people were elected to membership in the Society: J. J. Radford; Y. Y. Spotsky; John Ustation.

Under the heading "Preview of the Summer Skies", Miss R. J. Northcott gave the annual talk on the OBSERVER'S HANDBOOK, with special reference to the positions of the planets this coming season. Miss Northcott explained what was meant by the various symbols in the OBSERVER'S HANDBOOK so those who attended would be able to read the pages entitled "Astronomical Phenomena Month by Month" intelligently. Miss Northcott also drew attention to the coming transit of Mercury on November 14, 1953, so all amateurs would be prepared to observe it if the weather permits.

Miss B. R. Creeper gave a short talk on an object of current interest, the newly discovered Wilson's asteroid.

The meeting was adjourned early so members would have an opportunity to observe through the telescopes which were set up on the campus.

October 13, 1953—The meeting was held at the David Dunlap Observatory, Richmond Hill. The First Vice-President, Dr. William R. Hossack, was chairman.

Dr. Heard welcomed the Society on behalf of the staff, and introduced Dr. Donald A. MacRae and Dr. J. B. Oke who are newcomers to the staff. The business meeting then adjourned, and the tour of the Observatory began. The evening was clear, so the members were able to see M15 through the 74-inch telescope, the Ring Nebula in Lyra through the 19-inch telescope and the Andromeda nebula through the 6-inch, unless there was a special request for another object. Dr. Hossack demonstrated the microphotometer and the oscilloscopic microphotometer, the latter an instrument for measuring radial velocities and stellar luminosities which Dr. Hossack designed and constructed himself.

October 27, 1953—The meeting was held in the McLennan Physics Laboratory with Dr. William R. Hossack, First Vice-President, in the chair.

The following were elected to membership in the Society: (all from Toronto unless otherwise stated): James W. L. Arter; Edwin V. Austin; Miss Avril Barr; Warren R. Coryell; Carl-Arne Croneland; Peter W. Dean; Evan A. Dickson; William A. Dow (Oakville); Thomas J. Ferris; Patrick Folkes; Ben Glanzer (Washington, D.C.); Lionel S. Gonin (Belleville); Edmund R. Greszczyszan; George E. Hawkins; C. Richard Hopkins; James R. Hughes; Robert H. Hunt (Brantford); William E. Kane (Vermilion, Ohio); Peter G. LaFlair; Lester S. Locke; Miss Mary M. Maclean; Hector G. McMurdo; Miss Kristina M. Nellin; Robert M. R. Nicholls; Ernst Nielsen; G. Peter Nixon; Jerry Olynk; Miss Marguerite Palmer; John Pare; Zigmund Parkin; Miss Nellie E. Parr; Miss Alida A. Penton; Christopher R.

Purton (Inglewood); Joseph J. Radford; Cecil Rotenberg; Alfred W. Scott; George Sotiroff; Yurko Spolsky; Richard J. Stanton (Baker Lake, N.W.T.); John Ustation; George B. Varcoe; Urho Johannes Vuori (Dunnville); Joel L. Walker; William R. Weldon; Alan E. Wilson; Irwin Zack. Donald W. Boyd transferred to the Toronto Centre.

The speaker of the evening, Mr. Ian Halliday of the positional astronomy division at the Dominion Observatory, Ottawa, was introduced by Dr. Hossack. The subject of Mr. Halliday's lecture was "Palomar Explores the Universe".

The purpose of a large telescope is to get larger light gathering power and hence to be able to photograph fainter objects, such objects as the external galaxies. These galaxies are classified according to their appearance, that is, according to the degree of ellipticity they possess and to the development of the spiral arms. With a large telescope, photographs reveal clusters of galaxies which may contain as many as 100 members. These photographs also show, in the cases of the larger and closer galaxies, that they contain objects which are common to our Milky Way system, such as variable stars, novae, and in some of the galaxies, interstellar material.

Mr. Halliday next discussed the methods for obtaining the distances of the external galaxies. The oldest method made use of the fact that if you know how bright an object really is, i.e. its absolute magnitude, and if you know how bright it appears to be, then you are able to compute the distance. Energy is inversely proportional to the square of the distance, and light is a form of energy. In our own galaxy it had been found that in the case of the Cepheid variable stars, there is a relation between absolute magnitude and the period of light variation. When Cepheid variables were discovered in nearby galaxies, this method was used to compute the distances. However, when they tried to pick up short-period Cepheids in the Andromeda nebula with the 200-inch, they discovered they were not being very successful. This led to the conclusion that for these variables to appear so faint, the Andromeda nebula must be twice as far away as they believed. The reason for this error was that statistical methods had been used on the classical long-period Cepheids, since no direct or trigonometric parallaxes were available. This doubling of the distance to the Andromeda nebula fixes up some other discrepancies, such as making the emission patches in our galaxy the same size as those in other galaxies and making the diameters of the Cepheid variables twice as large which means they now fit into the theories of pulsation. Other methods of obtaining the distances of galaxies make use of novae and surface brightness. Statistical analysis is used to obtain the distances of clusters of galaxies.

The radial velocities of the galaxies have been measured, and it has been shown that the further out into space one goes, the greater the shift to the red of the lines in extra-galactic spectra. This had led to the theory of the expanding universe. The alteration in distance means that the expansion could have been proceeding for twice as long as it had previously been thought, and this would be longer than the existence of the earth.

One of the most interesting aspects of our galaxy is the dust clouds where the stars are believed to be born. In large groups of galaxies, collisions are inevitable—some will have had 10 or 20 since the universe began. In such a collision, not more than one or two stars will collide, but the interstellar dust would be swept out because the density is so great. This would leave the galaxies without gas, the gas being left between the galaxies. Theory has shown that galaxies in collision should

emit radiation of radio frequency such as that which has been observed in the Cygnus region. Observational support of the theory that the gas is left between the galaxies has been found by trying to photograph distant galaxies through a nearby cluster of galaxies. The photographs showed six in this region as compared to 75 in a region that was free from galactic clusters.

Mr. L. H. Clark expressed the appreciation of the Toronto Centre for Mr. Halliday's talk. The meeting was adjourned.

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